[Al, you can do a one-for-one replacement of “Web” and “IPG”.]

We seek to understand the kinds of information NASA workers share, the social and methodological frameworks they prefer, how this information is managed and presented, and the various roles desktop tools and automated agents will assume in distributed, collaborative activity. We need to develop information technologies that increase teamwork, comprehension, and efficacy, while reducing miscommunication, error, and loss of information. Interfacing with NASA staff will enable an understanding of the daily activities and how they can be supported effectively with information technology applications. Each entity (human or machine) within a domain is a potential source of information and knowledge. Intelligent agents can provide assistance to people in a collaborative environment.

We recognize that the World Wide Web is being extended into space. An example was collecting real-time information from the Lunar Prospector and disseminating it onto the Web. Communication and management of heterogeneous (and possibly massive) information sources are essential. Tools will be needed to enable ground-space teams to coordinate activities, in part, through the computing medium using existing NASA tools mentioned above. On-board mass storage and space-ground data links will allow NASA to leverage the Web in space. This will make possible web-based collaborative systems design, groupware, work systems simulation, information technologies, information visualization, intelligent agents, data and information analysis techniques, knowledge-based systems, and more.

In essence, putting a spacecraft such as the shuttle or a space probe on the web makes communication with that spacecraft as transparent as launching a web browser. All of the technology of the web is then available to query the health and status of the spacecraft, view data from its instruments in real time, interact with its systems or astronauts, or perform command and control.

Researchers continually seek new ways to leverage information technology (IT) to improve the productivity and quality of their work. Numerical computation, computer control of instruments, data visualization, massive data storage, digital communication, and even desktop publishing have each enabled major improvements in the conduct of research. A new technology is emerging to advance the use of IT for research to the next level: comprehensive, domain-specific, remote-access, collaborative research environments hereafter called integrated synthesis environments (ISEs). ISEs will provide a means for researchers to finally integrate and automate all of the research activities listed above in a seamless environment, while hiding the vast amount of data, software, and interactions which are not of interest to them. Perhaps the most important goal for the IPG is to enable the creation and continual enhancement of ISEs as well their ubiquitous use.

Micro-Spacecraft Swarm. We propose a “swarm” of perhaps ten thousand tiny spacecraft, each on the order of a kilogram in mass, being launched from Earth to arrange themselves in a grid orbiting the Sun. These craft would be in constant contact with their immediate neighbors, and through this network, every spacecraft would be in contact with Earth. The microspacecraft would cooperate in performing a few well-defined functions: searching for and tracking Earth-threatening asteroids, detecting and quantifying anomalous solar activity, detecting and filling in vacant swarm observation posts, and relaying this information through the swarm network to Earth. It would be impossible for any Earth-based system to adequately control the swarm due to the vast

numbers, the communication delay, the location of part of the swarm on the opposite side of the Sun from Earth, and the need for different parts of the swarm to formulate rapid and cooperative responses.

Graphic: Show the microspacecraft swarm in a grid (yellow interconnection lines signifying communication with nearest neighbors) around the sun. The grid fades into the distance on the far side of the Sun. The Earth can be seen far away and 90 degrees around the Sun, and is one of the nodes on the grid. In the foreground, several microcraft determine the trajectory of a hurtling asteroid (show waves sent out from microcraft and bouncing off asteroid). On the side of the Sun opposite Earth, several microcraft monitor a huge solar flare.